CLAIMS

WE CLAIM:

1. A method for removing a sacrificial material that is disposed within a gap between two structural layers of a microstructure using a vapor phase etchant recipe, the method comprising:

determining a size of the gap;

preparing the vapor phase etchant recipe such that a mean-free-path of the etchant recipe corresponds to the gap size; and

removing the sacrificial material of the microstructure using the prepared etchant recipe.

2. The method of claim 1, wherein the step of preparing the vapor phase etchant recipe further comprises: preparing the etchant recipe such that the mean-free-path of the etchant recipe is equal to or less than a value that is 2 times the gap size.

3. The method of claim 1, wherein the step of preparing the vapor phase etchant recipe further comprises: preparing the etchant recipe such that the mean-free-path of the etchant recipe is equal to or less than a value that is 1.5 times the gap size.

4. The method of claim 1, wherein the step of preparing the vapor phase etchant recipe further comprises: preparing the etchant recipe such that the mean-free-path of the etchant recipe is equal to or less than a value that is 90 percent of the gap size.

5. The method of claim 1, wherein the step of preparing the vapor phase etchant recipe further comprises: preparing the etchant recipe such that the mean-free-path of the etchant recipe is equal to or less than a value that is 50 percent of the gap size.

6. The method of claim 1, wherein the step of preparing the vapor phase etchant recipe further comprises: preparing the etchant recipe such that the mean-free-path of the etchant recipe is from 90 percent of the gap size to 1.5 times the gap size.

7. The method of claim 1, wherein the minimum gap size is 1.5 micrometer or less.

8. The method of claim 1, wherein the minimum gap size is 0.5 micrometer or less.

9. The method of claim 1, wherein the sacrificial material is amorphous silicon.

10. The method of claim 1, wherein the step of preparing the etchant recipe further comprises: preparing the etchant recipe by mixing a spontaneous vapor phase etchant and a diluent gas, wherein the etchant is selected from the group comprises an interhalogen gas, a noble gas halide and HF.

11. The method of claim 10, wherein the interhalogen comprises bromine trifluoride; and wherein the noble gas halide comprises XeF_2.

12. The method of claim 8, wherein the diluent gas is selected from a group comprising He, N_2, Ar, Kr, Ne and Xe.

13. The method of claim 10, wherein the step of preparing the etchant recipe further comprises: providing the etchant recipe by mixing a spontaneous vapor phase chemical etchant and a diluent gas such that a total pressure of the etchant recipe is from 1 to 700 torr.

14. The method of claim 10, wherein the etchant recipe has a total pressure higher than 10 atmospheres.

15. The method of claim 13, wherein the etchant has a partial pressure of from 1 to 15 torr.

16. The method of claim 10, wherein the diluent gas has a partial pressure of from 1 to 700 torr.

17. The method of claim 16, wherein the diluent gas has a partial pressure greater than 2 atmospheres.

18. The method of claim 13, wherein the diluent gas has a partial pressure of from 50 to 100 torr.

19. The method of claim 10, wherein a ratio of a partial pressure of the etchant gas and a partial pressure of the diluent gas is from 1/1000 to 1/10.

20. The method of claim 19, wherein the ratio is from 1/100 to 3/50.

21. The method of claim 10, wherein the mean-free-path of the etchant recipe is equal to or less than 1.0 micrometer.

22. The method of claim 10, wherein the mean-free-path of the etchant recipe is equal to or less than 0.5 micrometers.

23. The method of claim 10, further comprising:

determining an amount of the etchant to be fed into the etching system;

setting a pressure inside an exchange chamber corresponding to the determined amount of the etchant;

filling the determined amount of the etchant into the exchange chamber;

filling an amount of the diluent gas into the exchange chamber; and

feeding the etchant recipe comprising the etchant and the diluent gas into the etching system.

24. The method of claim 23, wherein the diluent gas has a pressure determined according to the mean-free-path of the etchant recipe at a desired etching temperature;

25. The method of claim 24, wherein the etching temperature is 25°C or higher.

26. The method of claim 23, wherein the step of feeding the etchant recipe into the etching system further comprises:

feeding the etchant recipe into the etching system such that the amount of the etchant recipe fed into the etching system per unit time is equal to or higher than 0.5 liters per minute.

27. The method of claim 1, further comprising:

driving the prepared etchant recipe to flow through the sacrificial material of the microstructure such that the amount of the etchant recipe flowing through the microstructure per unit time is equal to or higher than 1/10 liter per second.

28. The method of claim 1, further comprising:

driving the prepared etchant recipe to flow through the sacrificial material of the microstructure such that the amount of the etchant recipe flowing through the microstructure per unit time is equal to or higher than 1/2 liter per second.

29. The method of claim 1, further comprising:

driving the prepared etchant recipe to flow through the sacrificial material of the microstructure such that the amount of the etchant recipe flowing through the microstructure per unit time is equal to or higher than 1 liter per second.

30. A method, comprising:

loading a microstructure having a sacrificial material disposed within a gap between two structural layers of the microstructure into an etch system, wherein the gap has a size less than 1.5 micrometer;

preparing a vapor phase etchant recipe such that a mean-free-path of the etchant recipe is equal to or less than the gap size; and

removing the sacrificial material of the microstructure using the prepared etchant recipe.

31. The method of claim 30, wherein the gap size is around 0.5 micrometer or less.

32. The method of claim 30, wherein the sacrificial material is amorphous silicon.

33. The method of claim 30, wherein the step of preparing the etchant recipe further comprises: preparing the etchant recipe by mixing a spontaneous vapor phase etchant and a

diluent gas, wherein the etchant is selected from the group comprises an interhalogen gas, a noble gas halide and HF.

34. The method of claim 33, wherein the interhalogen comprises bromine trifluoride; and wherein the noble gas halide comprises XeF_2.

35. The method of claim 33, wherein the diluent gas is selected from He, N_2, Ar, Kr, Ne and Xe.

36. The method of claim 33, wherein the etchant recipe has a total pressure from 1 to 700 torr.

37. The method of claim 33, wherein the etchant recipe has a total pressure higher than 2 atmospheres.

38. The method of claim 33, wherein the etchant has a partial pressure from 1 to 15 torr.

39. The method of claim 33, wherein the diluent gas has a partial pressure from 1 to 700 torr.

40. The method of claim 33, wherein a ratio of a partial pressure of the etchant gas to a partial pressure of the diluent gas is from 1/1000 to 1/10.

41. The method of claim 33, wherein the ratio is from 6/100 to 4/200.

42. The method of claim 33, wherein the mean-free-path of the etchant recipe is equal to or less than 0.5 micrometers.

43. The method of claim 30, further comprising:

driving the prepared etchant recipe to flow through the sacrificial material of the microstructure such that the amount of the etchant recipe flowing through the microstructure per unit time is equal to or higher than 1/10 liter per second.

44. The method of claim 30, further comprising:

driving the prepared etchant recipe to flow through the sacrificial material of the microstructure such that the amount of the etchant recipe flowing through the microstructure per unit time is equal to or higher than 1/2 liter per second.

45. The method of claim 30, further comprising:

driving the prepared etchant recipe to flow through the sacrificial material of the microstructure such that the amount of the etchant recipe flowing through the microstructure per unit time is equal to or higher than 1 liter per second.

46. A method, comprising:

loading a microstructure having a sacrificial material disposed within a gap between two structural layers of the microstructure into an etch system;

preparing a vapor phase etchant recipe such that a mean-free-path of the etchant recipe is equal to or less than 1.5 micrometers; and

removing the sacrificial material of the microstructure using the prepared etchant recipe.

47. The method of claim 46, wherein the gap has a size of less than 1.5 micrometers.

48. The method of claim 46, wherein the gap size less than 0.5 micrometers.

49. The method of claim 46, wherein the sacrificial material is amorphous silicon.

50. The method of claim 46, wherein the step of preparing the etchant recipe further comprises: preparing the etchant recipe by mixing a spontaneous vapor phase etchant and a diluent gas, wherein the etchant is selected from the group comprising an interhalogen gas, a noble gas halide and HF.

51. The method of claim 50, wherein the interhalogen comprises bromine trifluoride; and wherein the noble gas halide comprises XeF_2.

52. The method of claim 50, wherein the diluent gas is selected from He, N_2, Ar, Kr, Ne and Xe.

53. The method of claim 50, wherein the etchant recipe has a total pressure from 1 to 700 torr.

54. The method of claim 50, wherein the etchant recipe has a total pressure higher than 2 atmospheres.

55. The method of claim 50, wherein the etchant has a partial pressure of from 1 to 15 torr.

56. The method of claim 50, wherein the diluent gas has a partial pressure of from 1 to 700 torr.

57. The method of claim 50, wherein a ratio of a partial pressure of the etchant gas to a partial pressure of the diluent gas is from 1/1000 to 1/10.

58. The method of claim 57, wherein the ratio is from 6/100 to 4/200.

59. A method, comprising:

loading a microstructure having a sacrificial material disposed within a gap between two structural layers of the microstructure into an etching system;

preparing a vapor phase etchant recipe having a pressure higher than 2 atmosphere; and

removing the sacrificial material of the microstructure using the prepared etchant recipe.

60. The method of claim 59, wherein the vapor phase etchant recipe has a mean-free-path that is equal to or less than a size of the gap in the microstructure.

61. The method of claim 60, wherein the mean-free-path is equal to or less than 1.5 micrometers; and wherein the size of the gap is equal to or less than 1.5 micrometers.

62. The method of claim 60, wherein the mean-free-path is equal to or less than 0.5 micrometer; and wherein the gas size is equal to or less than 0.5 micrometer.

63. The method of claim 59, wherein the sacrificial material is amorphous silicon.

64. The method of claim 59, wherein the step of preparing the etchant recipe further comprises: preparing the etchant recipe by mixing a spontaneous vapor phase chemical etchant with a diluent gas, wherein the chemical etchant is selected from the group comprising an interhalogen gas, a noble gas halide and HF.

65. The method of claim 64, wherein the interhalogen comprises bromine trifluoride; and wherein the noble gas halide comprises XeF_2.

66. The method of claim 64, wherein the diluent gas is selected from a group comprising He, N_2, Ar, Kr, Ne and Xe.

67. The method of claim 64, wherein the etchant recipe has a total pressure of from 1 to 700 torr.

68. The method of claim 64, wherein the etchant recipe has a total pressure higher than 2 atmospheres.

69. The method of claim 64, wherein the etchant has a partial pressure of from 1 to 15 torr.

70. The method of claim 64, wherein the diluent gas has a partial pressure of from 1 to 700 torr.

71. The method of claim 64, wherein a ratio of a partial pressure of the chemical etchant gas to a partial pressure of the diluent gas is from 1/1000 to 1/10.

72. The method of claim 64, wherein the ratio is from 6/100 to 4/200.

73. A method for fabricating a micromirror, the method comprising:

preparing a substrate;

depositing one or more sacrificial layers;

forming a mirror plate and a hinge layer on the one or more sacrificial layers;

preparing a vapor phase etchant recipe such that a mean-free-path of the etchant recipe is equal to or less than a minimum thickness of the one or more sacrificial layers; and

removing the sacrificial layers using the prepared etchant recipe.

74. The method of claim 73, wherein the mean-free-path is equal to or less than 1.5 micrometer; and wherein the minimum thickness of the sacrificial layer is around 1.5 micrometers or larger.

75. The method of claim 73, wherein the mean-free-path is equal to or less than 0.5 micrometers; and wherein the minimum thickness of the sacrificial layer is around 0.5 micrometers or larger.

76. The method of claim 73, wherein the sacrificial material is amorphous silicon.

77. The method of claim 73, wherein the step of preparing the etchant recipe further comprises: preparing the etchant recipe by mixing a spontaneous vapor phase chemical etchant with a diluent gas, wherein the chemical etchant is from a group comprising an interhalogen gas, a noble gas halide and HF.

78. The method of claim 77, wherein the interhalogen comprises bromine trifluoride; and wherein the noble gas halide comprises XeF_2.

79. The method of claim 73, wherein the diluent gas is selected from a group comprising He, N_2, Ar, Kr, Ne and Xe.

80. The method of claim 73, wherein the etchant recipe has a total pressure of from 1 to 700 torr.

81. The method of claim 73, wherein the etchant recipe has a total pressure higher than 2 atmospheres.

82. The method of claim 73, wherein the chemical etchant of the etchant recipe has a partial pressure from 1 to 15 torr.

83. The method of claim 73, wherein the diluent gas has a partial pressure of from 1 to 700 torr.

84. The method of claim 73, wherein a ratio of a partial pressure of the chemical etchant gas to a partial pressure of the diluent gas is from 1/1000 to 1/10.

85. The method of claim 73, wherein the ratio is from 6/100 to 4/200.

86. The method of claim 73, wherein the step of depositing one or more sacrificial layers further comprises: depositing a first sacrificial layer between the substrate and the mirror plate and a second sacrificial layer between the mirror plate and the hinge layer.

87. The method of claim 86, wherein the second sacrificial layer has a thickness around 1.5 micrometers or less.

88. The method of claim 86, wherein the second sacrificial layer has a thickness around 0.5 micrometers or less.

89. An etching system for removing a sacrificial material disposed within a gap between two structural layers of a microstructure, the system comprising:

an etchant source containing a spontaneous vapor phase chemical etchant that chemically reacts with the sacrificial material for removing the sacrificial material from the microstructure;

a diluent gas source containing a diluent gas;

an etch chamber containing the microstructure for preparing an etchant recipe having the chemical etchant, wherein the etch chamber further comprises:

a rotatable sample holder for holding the microstructure such that the microstructure rotates with the sample holder within the etch chamber;

an exchange chamber connected to the etchant source, the diluent gas source and the etchant chamber;

an chamber gate that is attached to the exchange chamber and the etch chamber for allowing a gas flowing between the exchange chamber and the etch chamber when the chamber gate is open; and

a pump connected to the exchange chamber for pumping out the gas in the exchange chamber out of the exchange chamber.

90. The system of claim 89, further comprising: a detector that measures a concentration of a chemical species that is selected from a group comprising: the etchant, the diluent gas and an etch product generated from a chemical reaction between the etchant and the sacrificial material.

91. The system of claim 90, wherein the chemical species s the concentration of the chemical etchant.

92. The system of claim 89, wherein the etch chamber further comprises: an agitator for agitating the etchant recipe within the etch chamber.

93. The system of claim 89, further comprising: a circulation loop connects the etch chamber and a circulation pump.

94. The system of claim 89, wherein the etch chamber has a vapor phase etchant recipe that further comprises the spontaneous vapor phase etchant and the diluent gas; and wherein the vapor phase etchant has a mean-free-path equal to or less than 1.5 micrometer.

95. The system of claim 94, wherein the etchant recipe has a mean-free-path equal to or less than 0.5 micrometer.

96. The system of claim 89, wherein the etch chamber has a vapor phase etchant recipe that further comprises the spontaneous vapor phase etchant and the diluent gas; and wherein the vapor phase etchant has a pressure equal to or higher than 2 atmospheres.

97. The system of claim 89, wherein the etch chamber has a vapor phase etchant recipe that further comprises the spontaneous vapor phase etchant and the diluent gas; and wherein the vapor phase etchant has a temperature around 25°C degrees or higher.